

Synopsis

Pollution is the single largest cause of transmission/distribution line outages, next to lightning, which result in expensive power outages. A major significance of the problem is that it can repeatedly occur even at normal working voltages. As a result, it has become the most detrimental factor affecting the safe operation of extra and ultra high voltage (EHV/UHV) transmission lines and substations. In reality, the phenomenon of pollution-induced flashover is a very complex, and vexatious problem that continues to challenge high voltage engineers even today. In spite of knowing this phenomenon for the past several decades, a solution has remained still elusive.

Although there exist some remedial measures, there are associated limitations, which will become evident on long runs. The guaranteed solution seems to be the washing and cleaning of insulators for which utilities spend significant amount of money. Therefore, there is a need to develop a suitable mitigation technique which is cost effective and yield better performance in the field.

Motivated by this, the present study is undertaken and it essentially aims to seek simple alternative solutions for the problem for strings with ceramic insulator discs. All the ten types (normal and anti fog) ceramic insulators, which are commonly employed in our country, are considered in the study. Amongst the several controllable and uncontrollable physical quantities leading to the pollution flashover phenomena, the maximum surface field is identified as one of the major influencing factor. In fact, the field concentration near the pin can lead to early formation of dry band and scintillation/partial arcs. Considering this, it is intended to seek possible minimization of the maximum surface field occurring at the pin region. This is expected to yield enhanced pollution/contamination flashover strength and in addition, show an improvement in normal operation.

The intended study requires a detailed knowledge on field distribution. However, the required data is found to be rather scarce. In view of this a detailed study on field distribution is taken up for all the ten types of disc insulators used in our country.

For the problem under investigation, the governing equation has been identified for both clean and polluted conditions along with pertinent boundary conditions. Considering the open geometry nature of the problem along with presence of multiple dielectrics, Surface Charge Simulation (SCSM) methodology was found to be most

suitable and hence adopted for the work. In particular, the Galerkin method with piecewise linear interpolation function is employed in the formulation. The method employed and the codes developed are verified with suitable examples.

First, a detailed quantification of the field distribution under clean conditions is made for all the ten types of discs in single disc and string configuration. Subsequently, the task of reducing the maximum surface field gradient, which occurs at the pin is attempted. Several consideration lead to an artificial extension of pin as one of best feasible choice. However, any attempt to extend the pin would lead to some reduction in total creepage length, possible enhancement of bulk stress in air and enhancement of stress in triple junction. After a careful study, involving several experimental trials, a novel field control element (FCE) is developed both for normal and anti-fog types of insulator discs.

From the electric field simulation study, it is shown that the use of field control element for uniform pollution deposition prevailing under laboratory test conditions yields a significant reduction of maximum surface field for discs by about 47 to 54%. Similarly a reduction of about 37% to 55% in case of 3-disc string (for 33 kV class), 30% to 52% in case of 9-disc string (for 132 kV class), 27% to 52% in case of 14-disc string (220 kV class), 27% to 54% in case of 23/20 disc string (for 400 kV class) and 41% to 48% in case of 35/29 disc strings (for 765kV class) is achieved respectively for different strings. It is anticipated that this will lead to retardation in inception of scintillations/partial arcs, which in turn can reduce the risk of pollution induced flashover.

Subsequently, it was aimed to experimentally evaluate the impact of field control element on the performance of disc/string under normal and that during polluted conditions. For this a national level unique artificial pollution test facility as per the international standards has been established for conducting pollution studies on disc insulator/strings up to 132kV system voltage (The rating of test source: 150kV/2A, 100kV/3A, 50kV/6A of 300kVA).

Experimental investigations for the normal operation involving dry and wet power frequency flashover strengths, lightning impulse strength, radio interference level (RIV), visible discharge inception (Corona) level and voltage distribution along the string are carried out. The study showed that with the insertion of field control element, performance under normal condition is maintained and in fact noticeably improved in certain cases. Subsequently pollution flashover strength is evaluated using solid layer and cold fog methods. The pollution flashover strength exhibited an overall improvement 15 to 20% for all types of discs considered in the study. Similarly an

improvement of 16 to 19% and 12-14% is observed for 3-disc string and 6-disc string respectively.

The reasons for relatively lower gain in the pollution flashover strength as compared to reduction in maximum surface field are investigated. In particular, the reduction in improvement with number of discs in a string is dealt with. The non-uniform wetting against highly non-uniform drying of insulator surface and discs in a string, are identified as the cause for deviation. For an experimental verification of the same, the pollution layer resistance of individual discs in a 3-disc string is measured prior to and immediately after flashover. It is shown that the resistances of the different units become grossly different even though initial values were substantially the same. The values measured immediately after flashover show that the resistance of the top unit develops voltage enough to result in its flashover and subsequently, the flashover of the whole string.

In summary, the main contribution of the present work is the development of novel field control element (FCE) for both normal and anti-fog type of ceramic disc insulators, which will enhance their pollution flashover strength. The actual cost of these elements is estimated to be about 1-2% of the cost of the disc, while the gain in strength is shown to be more than 12 - 20%.